Fermilab

Fermi National Accelerator Laboratory
P.O. Box 500 • Batavia, Illinois • 60510

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BCP Facility: Ventilation System

C. Boffo, Y. Terechkine

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1. Introduction

The polishing of Nb RF cavities, either by means of BCP or of EP, requires a rather big amount of acid (between 10 and 55 gallons) and the results of the chemical reactions include NO_x plus vapors of HF, HNO_3, and, in the case of EP, H_2SO_4.

The process is performed in an enclosed compartment with the ventilation exhaust connected to a wet scrubber. According to the projected gas release [1], a scrubbing system capable of 3000 cfm will provide the correct ventilation to the room during the chemical process. This note describes the design of the ventilation system.

2. Sources of air pollutants

The FNAL BCP setup is based on the concept of using gravity to fill the process tank (with a cavity to be processed inside) with acid [2].

There are nine containers in the process room; seven of them can contain acid:

1. The process tank T5 where a cavity to be processed is contained;
2. The acid gravity feed tank T1 that is used to accumulate the needed amount of BCP acid mix before it is released to fill the process tank;
3. Acid waste tank T3, which is used to accept acid or acidic rinsing water from the process tank;
4. Pure acid barrel B1, which contains acid to fill the gravity feed tank;
5. Used acid barrel B2, which is used to collect all acid used in the process;
6. Emergency spill trench T0, which is a part of the process room and is used as a secondary safety feature that simplifies major spill handling;
7. Neutralization system tank

During the BCP process, a significant amount of NO_x is formed in the process tank T5. Besides, due to bubbling, a lot of foam and mist is produced that increases acid evaporation surface. The gas is extracted into a scrubbing system through a pipe welded on a lid of the tank. Air intake arrangement ensures proper filtering of the room air before it can enter the tank.

The acid gravity feed tank T1 is used only for acid short storage, so only the acid evaporation needs to be taken into the account. The gas is extracted through a pipe welded on the lid; intake gas, that enter while the tank is emptied, is filtered.

Although there is no main chemical reaction in the acid waste tank T3, due to foaming of the acid mixture coming from T5 and completing of certain secondary processes like oxidation reactions producing NO_x, a lot of outgasing is expected. The tank is covered with a lid, but due to the presence of several sensors, it appears necessary to put in place a small hood in order to safely and effectively catch the fumes.

The barrels B1 and B2 have to be connected to the system, and a local hood is used to protect personnel during this operation. Although the connectors itself are relatively small (size of about ½ ft), the fume hood is as large as the overpack of the barrel (effective size of about 2 ½ ft) for increased safety and to allow some small etching operations (e.g. preps) to be performed on large parts that do not fit into a standard ventilated hood.

The trench along the north wall is an additional area where local ventilation is necessary. In a case of a major spill, the acid is collected into the trench and transferred to a barrel B1 or B2 by means of a sump pump. During this process a 2000 cfm ventilation of the trench is recommended.

As it was mentioned earlier, in order to protect the surface of a cavity under process when T1 and T5 are emptied or filled, the make-up air that substitutes the acid must be clean and particle free. For this purpose two 1-µm 99.5% efficient filter are used in the make up air pipe for these tanks.

3. Duct positioning and dimensioning

This ventilation system is designed for extreme flexibility. Three different working scenarios have been identified:

1. Standard chemical process
2. Complete air wash of the compartment
3. Major spill

During normal operations, besides the general ventilation of the room, it is necessary to locally extract fumes from T1, T3, T5, B1, B2, and trench.

In case of complete air wash of the room only the general ventilation system is activated.

In the case of a major spill, most of acid is collected in the trench. So most of the ventilation should be directed to the trench while general ventilation must help in cleaning the room air. Fig. 1 shows the duct positioning and the ventilation openings in the enclosure and table 1 summarizes different options of ventilation:

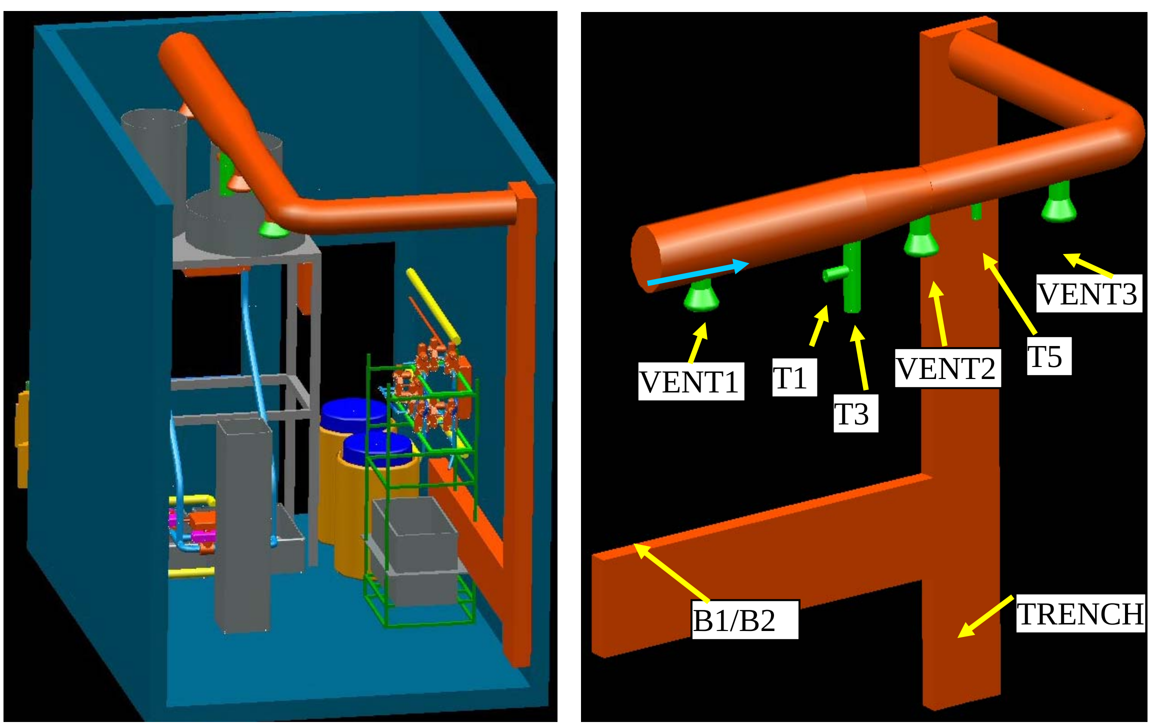

Fig. 1. Ventilation system for the BCP facility

	scenarios 1	2	3
T1	ON	OFF	OFF
T3	ON	OFF	OFF
T5	ON	OFF	OFF
B1/2	ON	OFF	OFF
TRENCH	ON	OFF	ON
VENT1	ON	ON	ON
VENT2	OFF	ON	OFF
VENT3	OFF	ON	OFF

Table 1 Operating branches of the ventilation system

The system can be divided into three different components:

1. Hard piping main line
2. Flexible piping from the main line to the local hoods
3. Local hoods

3.1. Local hoods

To prevent distribution of toxic gases and acid fumes all over the process compartment and beyond, it is straightforward to capture the gases into a ventilation system for later neutralization by a scrubbing system. The ventilation system must be designed to provide certain airflow in areas where gases are released.

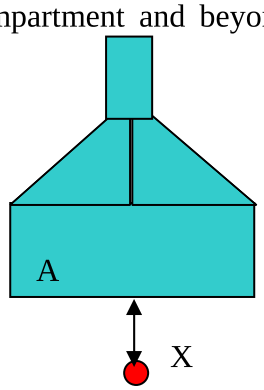

Fig. 2. Vent Hood

In the case of the tanks T1 and T5 the lids prevent NOx and the acid fumes from escaping out of the tanks. A 3" pipe is used to collect the fumes; this size allows a 100 cfm flow that guarantees an air speed in the pipe of about 2000 fpm. The air velocity of 2000 fpm is necessary to avoid condensation of the fumes on the piping walls [3]. The air filtering system for the make up air of T1 and T5 is designed for a 3 PSI pressure drop at 100 cfm.

Tank T3 needs a local hood of about 20"x10". Assuming that the source of fumes is 3" form the hood's inlet plane (see Fig. 2) and that, for a good capturing efficiency, the airspeed at the source is 200 fpm, a total flow of 400 cfm is calculated using the following equation [3]:

$$Q = V\cdot(10\cdot X^2 + A), \qquad /1/$$

where: Q is the air flow, cfm; V is the centerline velocity at X distance from the hood, fpm; X is the distance outward along axis, ft, and A is the area of hood opening, ft^2.
The effective diameter of a pipe connected to the hood must be about 5" to gain a 1500 fpm airspeed.

B1 and B2 need a hood with the effective size of 2 ½ ft. Assuming the working parameters accepted for the tank T3, a 1000 cfm flow is needed and a duct of 12" diameter should be connected to the hood. Due to geometrical constrains related to the presence of additional equipment in the area, a rectangular duct of 8"x14" is used instead. In order to allow for flexibility, the hood placed on top of the barrels is made of flexible PVC and is retractable.

At the interface between the hood (or the extraction pipe) and the flexible piping, a PVC butterfly valve is present. The valve is air operated and is used to activate the line remotely.
Table 2 shows the summary of the local ventilation systems.

	Flow rate		Diameter	Cross-section	speed	
	CFM	L/s	in	ft^2	fpm	m/s
T1	100	47	3	0.04908	2038	10
T3	400	189	5	0.13633	2934	15
T5	100	47	3	0.04908	2038	10
B1/2	1000	472	12	0.78525	1273	6
TRENCH	2000	944	12	0.78525	2547	13
VENT1	1000	472	6	0.19631	5094	26
VENT2	1000	472	6	0.19631	5094	26
VENT3	1000	472	6	0.19631	5094	26

Table 2. Local ventilation systems

3.2. Piping

The scrubber is connected to the room through a 16” PVC duct that enters the room at the west wall and is aligned with the process tank. The main pipe, as shown in Fig. 1, crosses the room staying near the roof and bends toward the floor at the north-east corner of the room with a transition from circular to rectangular cross section. All the connections between the hard duct and the local hoods are made using flexible pipes.
In order to allow for the general scrubbed ventilation of the room, thee diffusers with a nominal flow rate of 1000 cfm are present in the main pipe (VENT1, VENT2, VENT3).
The piping dimensioning is performed using the standard constant pressure drop method.
The results are shown in Table 3 with the numbering illustrated by Fig. 3.

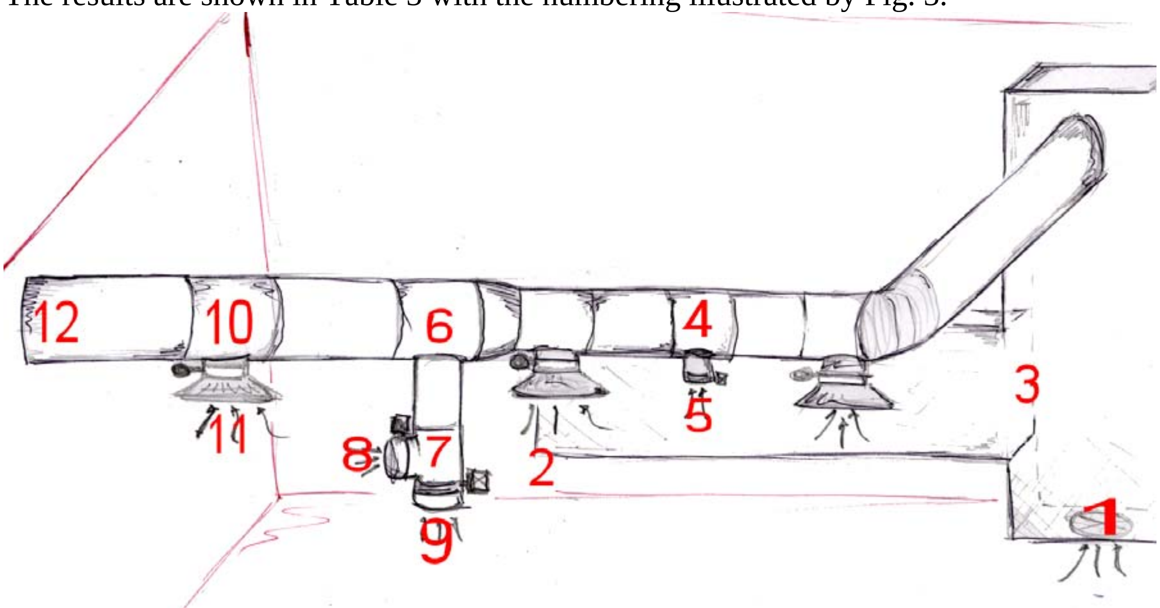

Fig. 3. Piping map used for calculations

Differences in pressure drop of the single parallel channels due to different vents opening can be corrected by modifying the position of balancing flappers. The duct dimensioning is performed considering the standard chemical process scenario 1 that assumes the next air flow rates at the points of fume capture:

T1	100 cfm
T3	400 cfm
T5	100 cfm
B1/B2	1000 cfm
TRENCH	600 cfm
VENT1	800 cfm

The only pipe designed for different flow rate with respect to this configuration, is the rectangular duct that connects to the trench since in case of major spill a flow rate of 2000 cfm must be used.

	Diameter	Flow rate		Cross section	Speed		dp/m	l	dp
	in	cfm	l/s	ft^2	fpm	m/s	Pa/m	m	Pa
1-3	12	600	283	0.785	764	3.9	0.75	1.2	0.9
2-3	12	1000	472	0.785	1273	6.5	4.5	3.1	13.95
3-4	12	1600	755	0.785	2038	10.4	3	6.9	20.7
5-4	3	100	47	0.049	2038	10.4	15	2.5	37.5
4-6	12	1700	802	0.785	2165	11.0	5	1.3	6.5
9-7	5	400	189	0.136	1467	7.5	8	3	24
8-7	3	100	47	0.049	2038	10.4	15	2	30
7-6	5	500	236	0.136	2201	11.2	17	1	17
6-10	16	2200	1038	1.396	1576	8.0	1.75	0.6	1.05
11-10	6	800	377	0.196	4075	20.7	40	1	40
10-12	16	3000	1416	1.396	2149	10.9	4	1.3	5.2

Table 3. Distributed pressure drop along the piping

4. System balancing and control

The ventilation system is controlled remotely from outside the enclosure where the process takes place. A small control panel with one button for each butterfly valve which controls each branch of the ventilation duct is integrated in the facility control panel. The buttons control directly the solenoidal valves that open and close the air lines of the air actuated butterfly valves without any intermediate PLC or logic component. The balancing of the air circuit is obtained with a one time operation by rotating the flappers present at each valve location and measuring the airspeed in the ducts.

5. References

[1] G. Barrett, et al., ANL-FNAL SRF Cavity Surface Treatment Facility. Air Pollution Issues, TD-03-056

[2] Y. Terechkine, et al., BCP Processing Facility, SRF-03, Lubeck, Germany, 2003

[3] ACGIH, Industrial Ventialtion, 21st edition 1992, chapter 3